DIFFRACTION GRATINGS FOR DIRECT IMAGE VIEWER

Final Report Phase II Trial #1

STATOTHR

[redacted]

DIFFRACTION GRATINGS

for

DIRECT IMAGE VIEWER

Report on Phase II

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1.0 The Diamond Tool

A fixture was designed and built for generating the short radius diamond tools required. (Photo included). Two diamond tools were made and were checked for radius and true arc, using a microscope with eyepiece scales specially made for this purpose. Each tool has two edges, and the four possible radii were measured and found to be in the range of 76 to 93 microns.

2.0 The Ruling Set Up

Several grating blanks were suitably coated with aluminum and all in the same run. Test grooves and test areas were ruled under various conditions of tool orientation and loading. Ruling and overruling was performed with various ruling depths for each pass.

2.1 Set Up Control

An interference microscope was used visually and photographically to find the best combination of tool orientation and loading, and to find the best combination of tool loadings for double ruling. Three micro-interferograms were measured for precise groove shape and the result plotted graphically. The first was of a single groove and was used to check the groove contour without the cross effects of adjacent grooves. The second was of adjacent grooves fully ruled in one pass, and clearly shows the unsymmetrical distortion caused by adjacent ruling. The third was of adjacent grooves ruled in two passes, and shows the considerable improvement in groove contour obtained by double ruling. Interferograms and graphs are included in this report.

3.0 Ruling and Replication

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A master ruling [redacted] was made, using the double ruling technique. The ruled area is 53 x 53mm and on a 58 x 58mm blank. Two transmission replicas of this ruling were made on blanks 58 x 58 x 10mm. The blank material is fine annealed BSC-2 glass.

4.0 Grating Tests

The distribution of energy among the orders of the transmission replicas was measured, and for six discrete wavelengths in steps of 10mμ, between 500 and and 550 mμ. The results were plotted on a bar graph.

4.1 Test 4.0 was simulated numerically and computed, assuming a theoretically correct groove shape. Results were plotted on a bar graph for comparison to 4.0.

4.2 Test 4.0 was simulated numerically and computed using the actual groove contour as plotted graphically from a micro-interferogram. The first computation was found to be inadequate in that the cubic least square fit used in deriving the groove shape coordinates was not close enough to the actual contour.

4.2.1 It thus became necessary to read manually 100 coordinates from the plotted groove contour, in order to derive computed energy distribution that could be compared in a meaningful way with the actual energy distribution. The time required to go through this additional work made it impossible to include the result in this report.

5.0 Test Results

The micro-interferograms have effective magnifications of 1050x across the groove and 14,500x for the depth of the groove. As plotted graphically, the magnification is approximately 10,000X and 100,000X respectively. The graphs also include a curve which is a true arc calculated from the measured width and depth of the groove. The departure of the groove profile from the true arc is 0.05 microns for a single groove, 0.26 microns for single ruled adjacent grooves, and 0.087 microns (3.4 micro inches) for double ruled adjacent grooves. The great advantage of double ruling is thus graphically illustrated.

5.1 The measured energy distribution among the orders for transmission grating #970 was examined for variation of the important ratios between them. For discrete wavelengths, 520mμ is the best choice with an overall maximum ratio of 6.4 to 1, between lowest and highest order, and 3.1 to 1, the greatest ratio between adjacent orders. However, when the entire wavelength region, 500 to 550mμ, is integrated and at the same time modified by the energy curve for a tungsten source and the spectral response of the eye, the overall effective ratio becomes 4.7 to 1, and 2.9 to 1 for adjacent orders. This comes fairly close to meeting the requirements of this grating.

5.1.1 It is quite evident from these graphs that even relatively small changes in wavelength have considerable influence on the nature of energy distribution amongst orders. One can also see that a suitable mixture or range of wavelengths, rather than a single narrow band, is capable of improving the uniform energy distribution problem.

5.2 By way of comparison, and for discrete wavelengths, the choice of wavelength for a theoretically perfect groove shape is also 520mμ, in which case the maximum overall intensity ratio is 1.9 to 1, and 1.7 to 1 for adjacent orders. This proves that the effect of wavelength, first noted experimentally, is confirmed by theory.

6.0 Conclusions and Recommendations

The test rulings herein described approach the theoretical distribution of energy, and should provide the means to some useful visual experiments that will tell how good the energy distribution has to be. More meaningful specifications can then be written. We can now see our way to three (3) possible ways of improving on the present test ruling. The first would be to triple rule instead of double rule. However, this would only lead us a little closer to the theoretical distribution, which at present appears to be barely acceptable.

The second way would be to alternate the ruling. We would rule every other groove and then rerule to fill in the spaces. This would lead to symmetrical grooves, but probably alternate grooves would differ in actual shape even if we were to double rule the alternate ruling. And again, we would only be approaching the uneven theoretical distribution of energy in the orders except with somewhat improved symmetry.

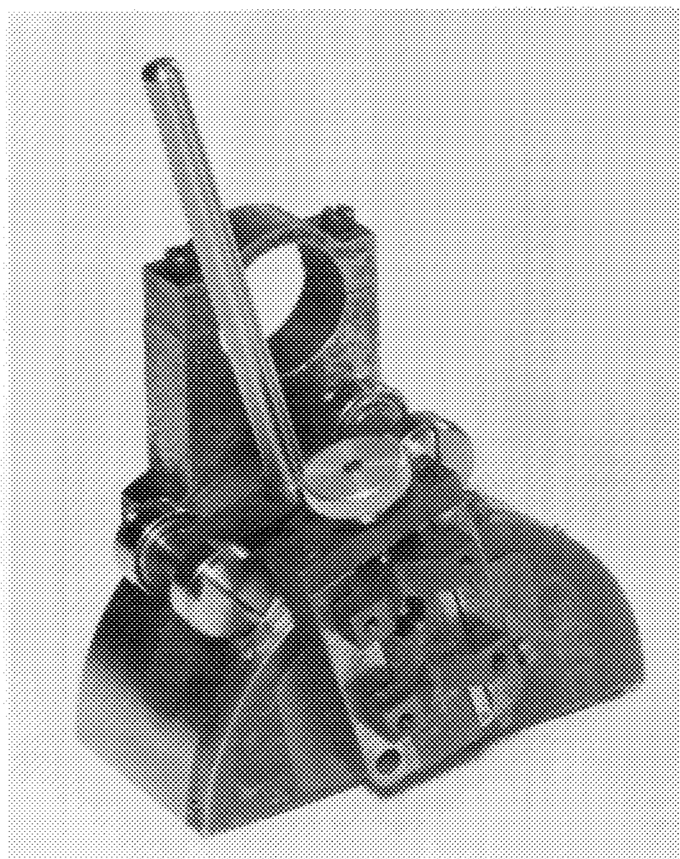
The third way would be to rule grooves twice as large. We would then have two orders everywhere we now have one order. This overlapping of orders should average the energy in the orders in use, namely, every other order. This third method seems the most promising to us in that we would be improving on the theoretical possibilities rather than merely trying to approach a less than perfect theoretical solution. On the negative side, the third method does introduce new problems. We would have to form grooves twice as large, necessitating reforming of much more material. Also, we should go back to Phase I type computation first to prove the theory of the energy distribution in the overlapping orders. Since the tool radius required will be roughly twice as large, a new set of tools will have to be made introducing a delay of one month. Nevertheless, it appears that Method 3 is the one most worthwhile to follow in Phase IIb of this project.

The following are appended to this report:

1. Photograph of diamond tool generating fixture
2. Micro-interferograms of groove profile
3. Graphs plotted from micro-interferograms
4. Bar Graph-Measured order intensities for discrete wavelengths
5. Bar Graph-Calculated order intensities for discrete wavelengths
6. Bar Graph-Relative order intensity for given source, receiver and band pass, derived from measured intensities.
7. Bar Graph-Calculated order intensities for discrete wavelengths derived from measured groove contour (Fig. 2).

Diamond Lapping Fixture

For generating short radius tools



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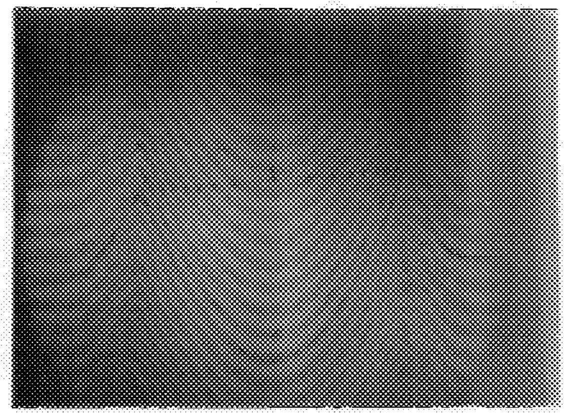
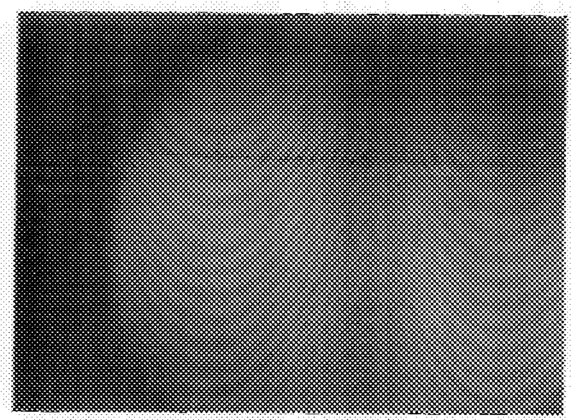
Micro-Interferograms of groove contour

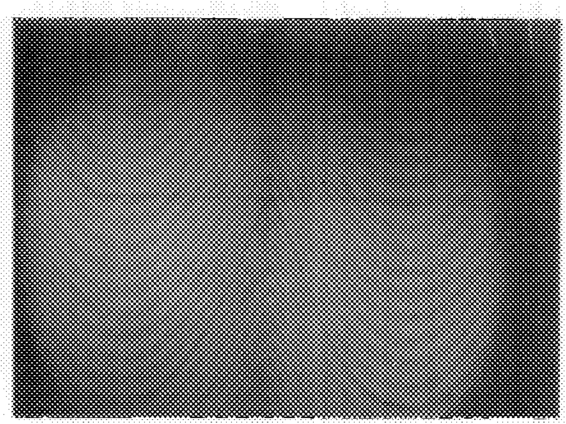
Magnification: 1050X Horizontal
14500X Depth



Micro-Interferogram of a single groove. 7 1/2 fringes (in oil) deep and 33.4 microns wide.



Micro-Interferogram of two adjacent grooves ruled in one pass. 10 fringes (in oil) deep and 36.2 microns wide.



Micro-Interferogram of two adjacent grooves ruled in two passes. 9 fringes (in oil) deep and 36.2 microns wide.

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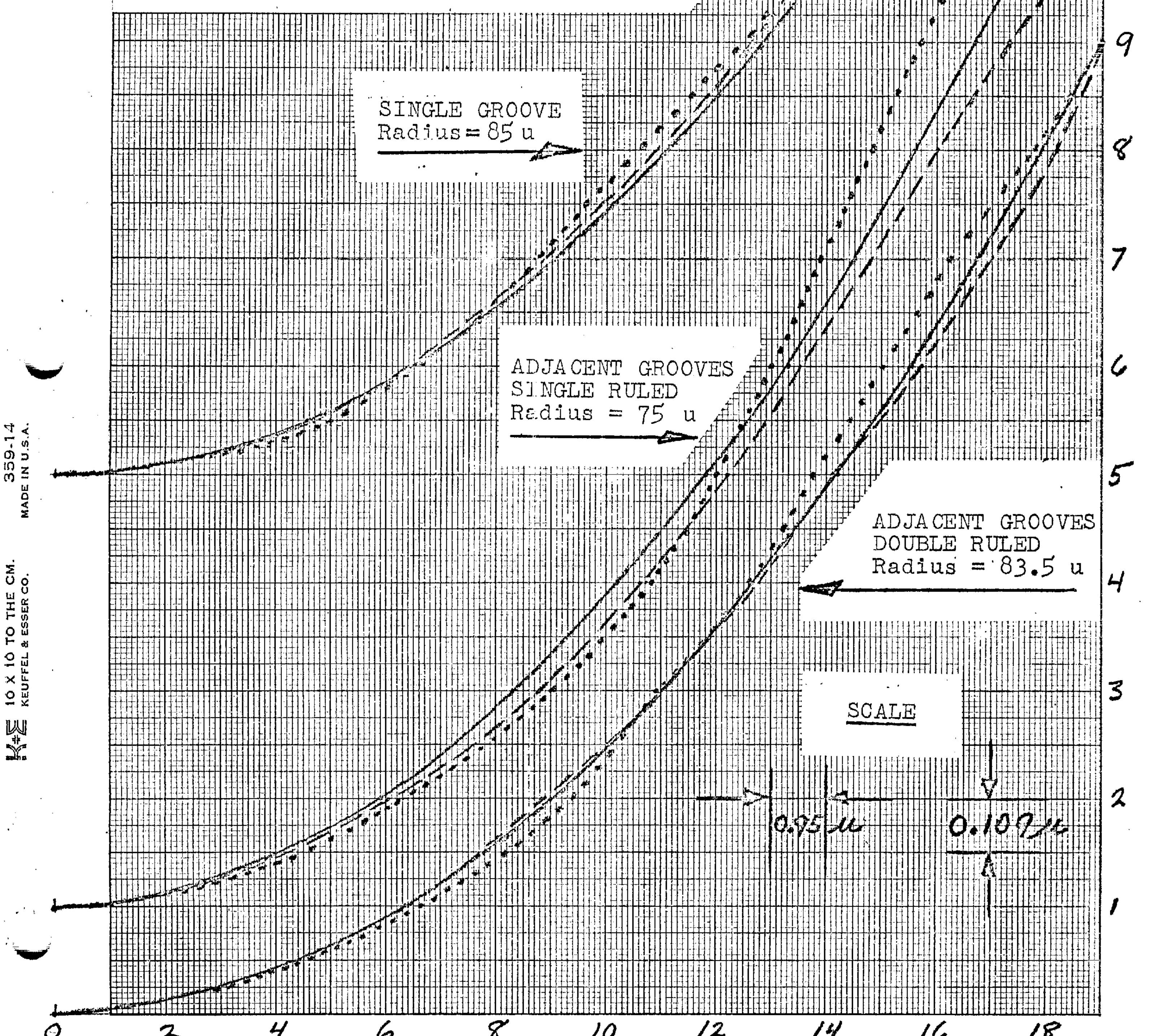
DATA PLOTTED FROM MICRO-INTERFEROGRAMS

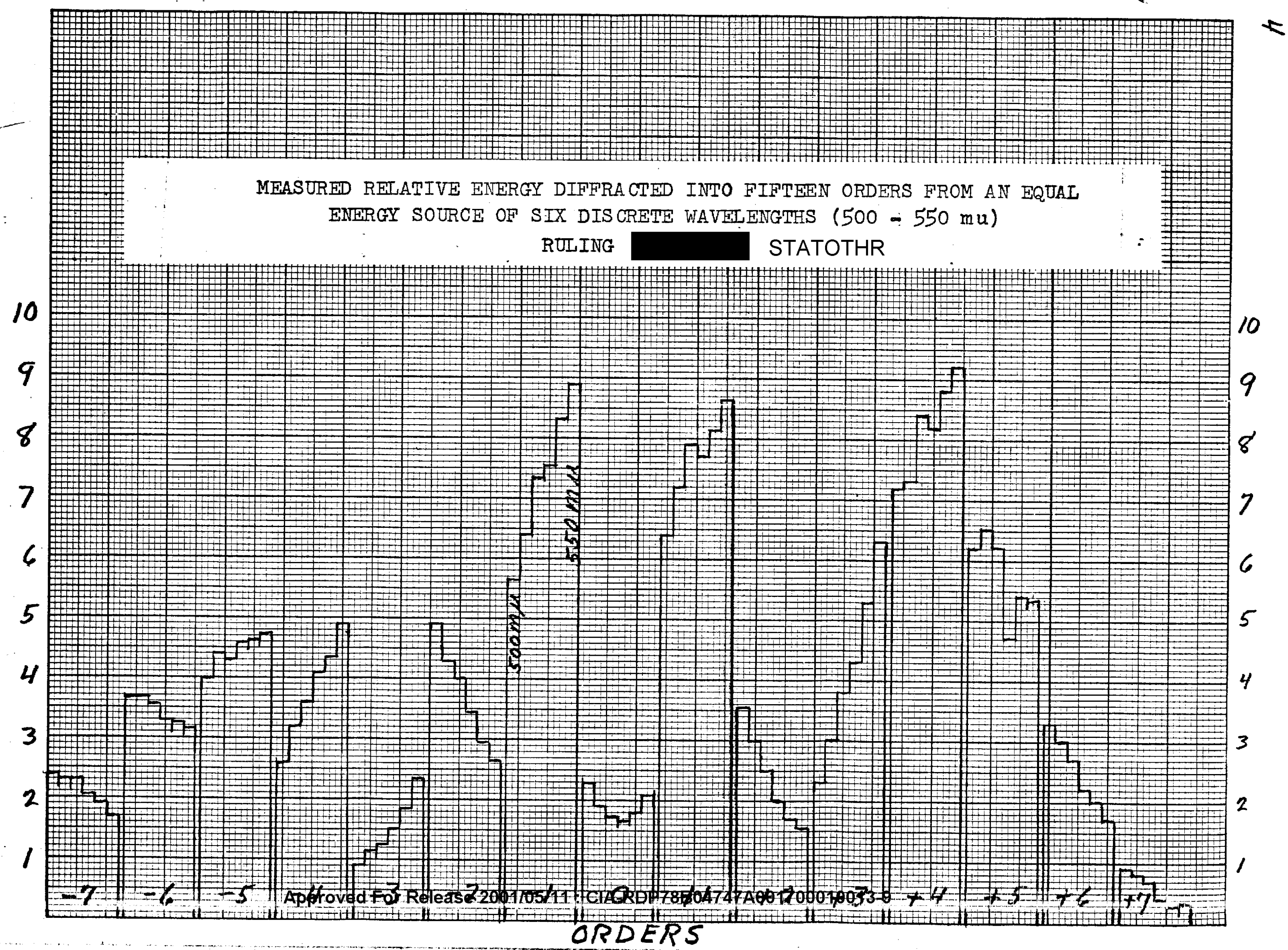
SOLID LINE - Radius calculated from width & depth of groove.

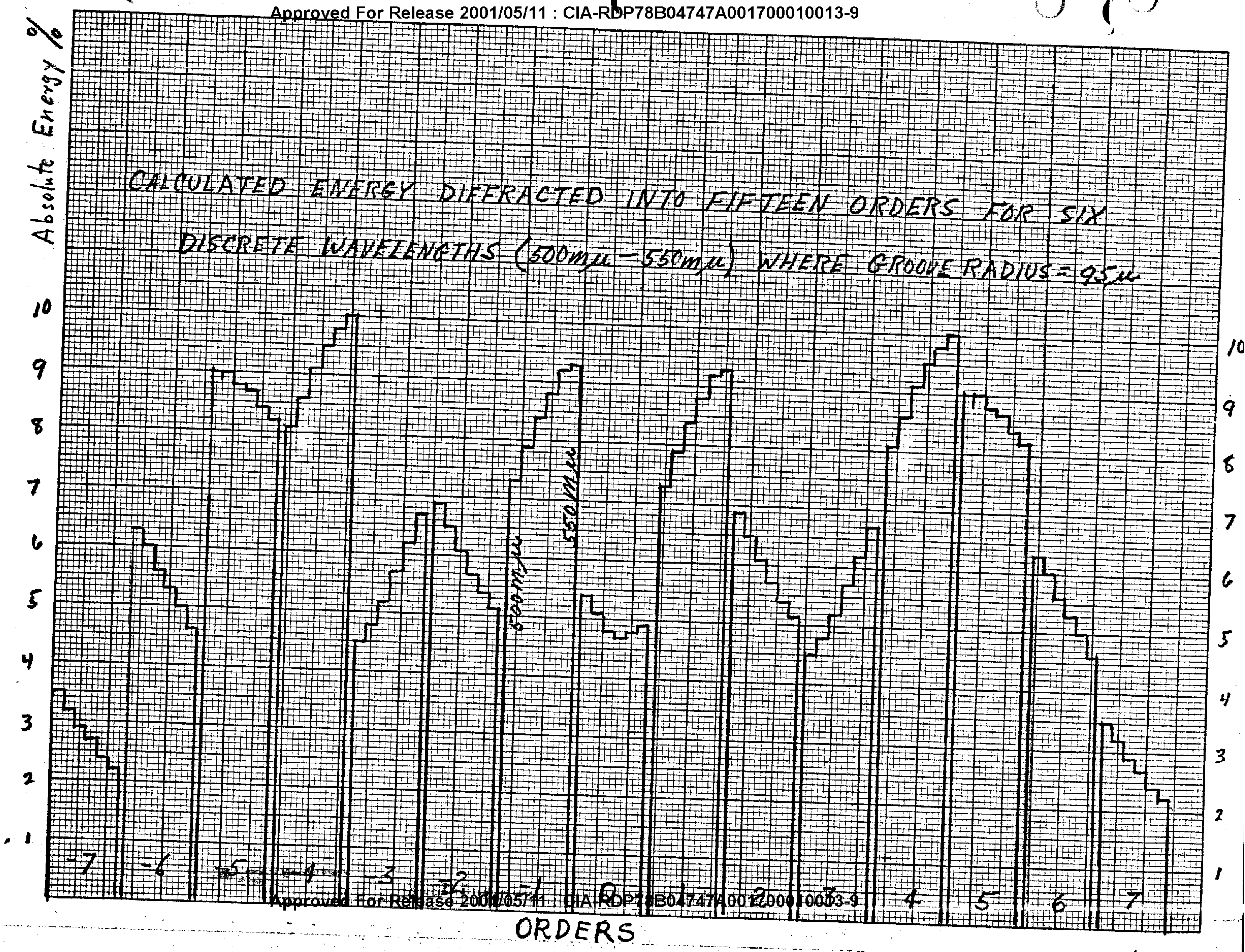
DASH LINE - Measured groove contour for leading side of groove.

DOTTED LINE Measured groove contour for trailing side of groove.

Ruling: [redacted] "




MEASURED RELATIVE ENERGY DIFFRACTED INTO FIFTEEN ORDERS FROM AN EQUAL ENERGY SOURCE OF SIX DISCRETE WAVELENGTHS (500 - 550 mu)
RULING [redacted] STATOTHR
10
9
8
7
6
5
4
3
2
1
500 mu
550 mu
-7
-6
-5
+4
+5
+6
+7
ORDERS



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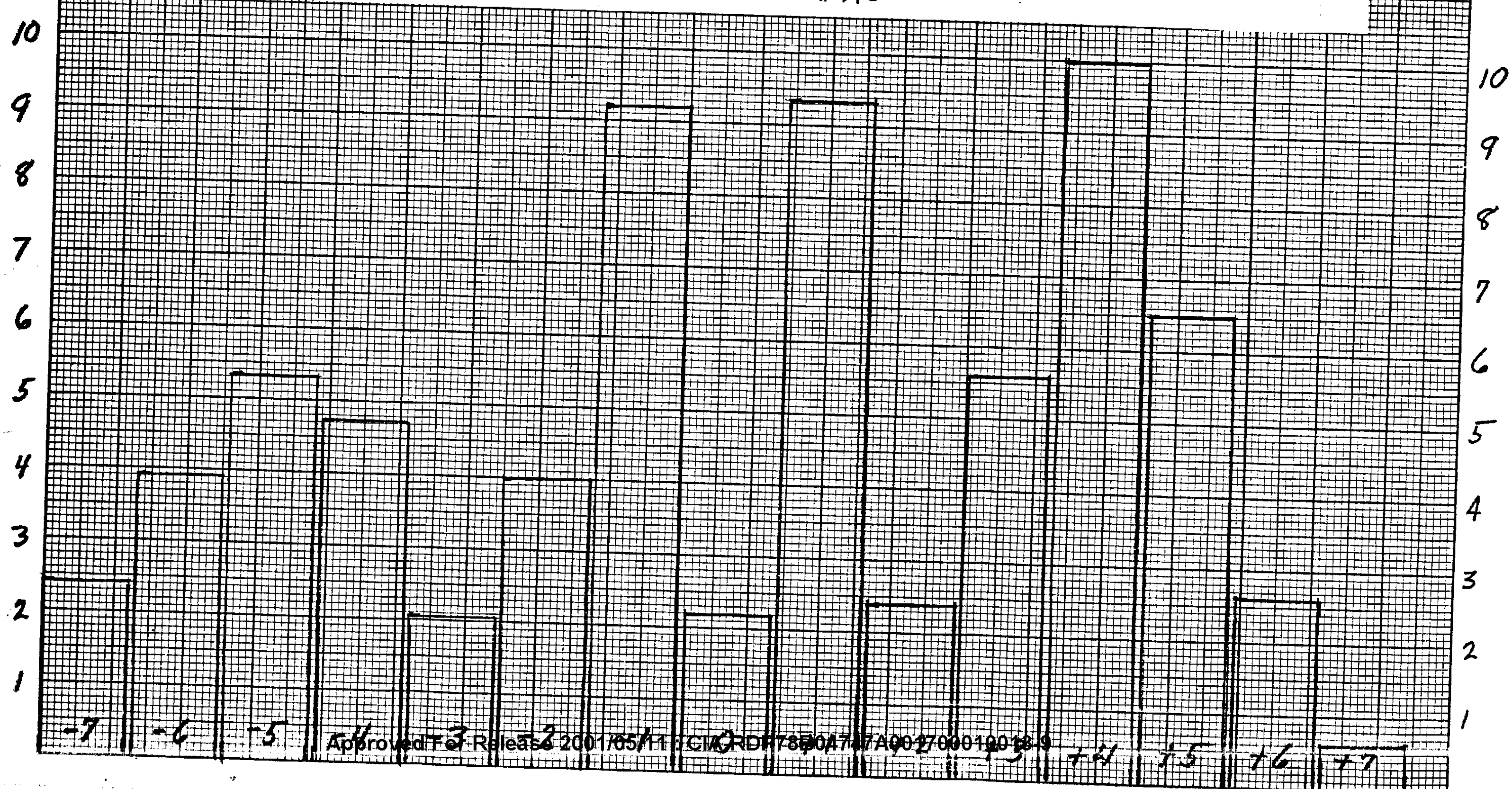
RELATIVE ENERGY DIFFRACTED INTO FIFTEEN ORDERS COMPENSATED FOR
TUNGSTEN SOURCE (500 - 550) AND EYE SENSITIVITY
BASED ON MEASURED DATA
OF RULING #970



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Calculated Energy Diffracted into Fifteen Orders for

Six Discrete Wavelengths (500–550mμ)

Data derived from 101 points on an Interferogram Groove Contour